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(19) (CA) APPLICATION FOR CANADIAN PATENT (12)

(54) Method and Apparatus to Improve Secondary Froth Quality Within Oil and Oil Extraction Processes

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(71) Same as inventor

(57) 10 Claims

Notice: This application is as filed and may therefore contain an incomplete specification.

ABSTRACT OF THE DISCLOSURE

A method to upgrade the quality of secondary froth obtained from a hot water extraction process and to improve treatment thereof comprising the steps of providing a froth cleaner, passing an untreated secondary froth stream into the froth cleaner for treatment, removing a low-bitumen content underflow stream from the froth cleaner, reheating at least a portion of the removed underflow stream and combining the reheated portion of the removed underflow stream with the untreated secondary froth stream prior to passing into the froth cleaner for treatment improving the performance of the froth cleaner and consequently increasing the quality of the cleaned secondary froth cleaner unit.

The present invention relates to an improvement to the hot water process for extraction bitumen from oil or tar sands.

Tar sand, also known as oil sand and bituminous sand is presently recognized as a valuable source of hydrocarbons. Numerous deposits of these sands exist throughout the world, the most extensive deposits being found in Northern Alberta, Canada. The only process in commercial use for the extraction of bitumen oil from oil sands is known as the Clark Hot Water Process.

In general terms, this process involves mixing the mined sands with water, steam and sodium hydroxide in a rotating tumbler or digestor to initially disperse the bitumen. The resulting slurry is discharged from the digestor and screened to remove large rocks and other reject material prior to dilution with additional hot water and introduction into a primary separation vessel (PSV). The PSV is a cylindrical vessel having a conical bottom where the diluted slurry is maintained at a temperature between 150 degrees to 185 degrees Fahrenheit. In the PSV, the sand settles to the bottom as tailings while the aerated and therefore more buoyant bitumen articles flow to the surface of the vessel to form a froth zone. The froth overflows the vessel wall and is received in a launder extending around its rim. This product is commonly referred to as "primary froth" and contains a high

percentage of bitumen, generally in excess of 60%. The bitumen-rich primary froth overflow is dearated and stored for further processing and extraction of the bitumen. A middlings stream typically comprising 2% to 4% bitumen along with fine solids and water is withdrawn from the mid-section of the PSV and is pumped to a sub-aeration flotation cell for further bitumen recovery. The middlings bitumen along with the continued water and solids is referred to as "secondary froth". Since the secondary froth has a lower percentage of bitumen and a higher mineral and water content it is less satisfactory for combination with the primary froth. Settling is then performed on the secondary froth to reduce water and solids content.

There have been several developments and trends with respect to the hot water extraction process that have caused the secondary froth cleaning steps of the process to assume greater significance in terms of overall economics and operability. It has been recognized that the hot water process should be operated to maximize primary froth production and to minimize the production of the secondary froth induced by air flotation cells. This is because, as noted above, the secondary-type froth is more heavily contaminated with minerals water and other solids than the primary froth. Typically, primary froth contains about

60% by weight bitumen whereas secondary froth contains only 10-45% by weight bitumen.

Furthermore, the middling stream which enters the flotation cells of the secondary extraction step often overflows the flotation cells for various reasons and combines with the secondary froth to further contaminate it. Because this material poses problems with downstream operations, it is passed out to a settling vessel known as a froth cleaner where water and minerals are allowed to settle out. The interface between the froth and slurry is maintained through operation of an underflow pump. The higher quality bitumen froth which overflows the froth cleaner is heated and dearated in a small heater prior to being combined with the primary froth for subsequent dearating and demineralization. Because the froth cleaner underflows contains residual bitumen, it is currently recycled to the flotation cells so that the residual bitumen will be recovered. Otherwise, this stream containing bitumen might be transferred directly to the tailings disposal system.

There have been a number of problems with froth cleaner operation of the secondary separation system. As ore reserves are depleted with existing operations, it has become more attractive to process lower grade tar sands having a higher fines content which previously would have

been rejected. Use of lower quality tar sands increases fines content within the system and leads to less primary froth, increased middlings and more amouns of secondary froth. This increase in secondary froth is caused in part because the bitumen dispersed from the primary separation step is more stable and therefore less inclined to be recovered as primary froth. Thus, more bitumen remains with the middlings and is therefore sent to secondary recovery thereby increasing load on that system. A plant operator must make numerous process adjustments to minimize the undesirable effects of low grade tar sand. In addition, there have been changes to the overall heat and energy requirements of the tar sands extraction plant such that low level heat has become less and less available thereby making the cost for conducting the hot water extraction process to be a matter of increasing concern. Thus, there has been a trend for existing and future operations to be geared toward an overall cooler and therefore less expensive extraction process. This will lead to production of a cooler froth of lower quality, thus making the upgrading of this froth even more important for efficient plant operation. Also, if bitumen is recovered from the tailings pond, a stream must be recycled to an appropriate location in extraction. This material stream is cold and of poor quality, causing a problem for the operation wherever it is introduced.

Addition of the Tailing Oil Recovery (TOR) step to the hot water process has also resulted in generation of more low-quality froth, which if transferred directly to froth treatment has a negative effect on capacity and bitumen product quality. In addition, transfer of this froth to the froth cleaner has a similar effect. As more low grade feed ore is processed, a greater proportion of froth is generated from the TOR operation. A need has therefore existed within the art to enhance the performance and capacity of the secondary recovery circuit and especially with respect to the froth cleaner circuit.

One such attempted is set forth in a paper entitled "A Method for Improving the Quality of the Bituminous Froth from Water Extraction of Oil Sands", Journal of Energy Resources Technology, Vol. 114, Dec. 1992 by R. Tipman and V.S.V. Rajan. In that process, low-quality froths from numerous process streams are combined and heated to about 90 degrees Celcius followed by settling of the product in a settling vessel. This approach necessitates a plant design which allows for gravity flow to a central heater or a separate froth heater and pump system for each of the various sources of low quality froth. Further, the type of heat exchangers required would be large and expensive due to the low heat transfer coefficient of the froth. Overall operating expenses are therefore increased if incorporating

such facilities within existing plant designs. Further, heating of the combined froth streams to extremely high temperatures, in this case as high as 120 degrees Celcius is not necessarily advantageous since froth temperatures above 95 degrees Celcius can cause it to lose entrained air and settle out in the froth cleaner rather than overflow as a dewatered product. This further upsets the froth cleaner unit and could cause additional loss of bitumen through the tailings stream.

An additional approach to remedy secondary recovery of bitumen and especially in regard to the froth cleaner is the direct addition of hot, clean water to the froth prior to settling. For example, U.S. Patent 3,738,903 (Kaminsky) discloses a secondary froth wash whereby the froth is deaerated, and subjected to intimate contact with fresh hot water. The contact causes the bitumen contained within the froth to release solids entrained within the bitumen, the water then separates from the bitumen allowing eventual recovery of the bitumen from the secondary froth. However, injection of hot clean water into the overall recovery circuit is considered undesirable Further, the capital expense for the required network of nozzles and associated piping would be very high.

Lastly, numerous efforts are being developed to enhance the quality of primary froth within the primary extraction circuit by various combinations of heating and

agitation. Consequently, a need has developed for alternative techniques of froth treatment which handle increased amounts of low quality secondary froth efficiently and reliably.

It has therefore been recognized as desirable to improve the hot water extraction process by increasing the quality of bitumen from the secondary froth. It is to this end that the present invention is directed. "Secondary froth" is intended to encompass any froth produced in connection with the hot water extraction process other than that produced in the primary extraction circuit.

The present invention is based upon the discovery that secondary froth can be efficiently upgraded within the froth cleaner to produce a higher quality froth and therefore bitumen product as well as to increase the pumpability of the secondary froth as it enters the froth cleaner. This is accomplished by diverting and heating a portion of the froth cleaner underflow for eventual recycle into the secondary froth stream prior to entering into the froth cleaner. This heated slurry of froth cleaner underflow and secondary froth has an increased temperature relative to the primary recovery circuit. It is sprayed into the flotation froth feed to the froth cleaner prior to introduction into the froth cleaner to heat and wash the secondary froth thereby increasing froth cleaner efficiency

and the quality of the froth cleaner product.

It is an object of the present invention to provide a process and apparatus that produces a froth cleaner product having a higher bitumen-to-solids ratio and also lowers the overall temperature requirements of the hot water extraction process.

Another object is to provide a low cost, low risk means for making the froth cleaner operation independent of upstream process temperatures.

A further object is to facilitate heating and transport of froth from flotation or a tailings oil recovery vessel to the froth cleaner without the need to inject fresh or dilution water.

Yet another object of the present invention is to provide a process for improving secondary froth quality the adjustment of which in terms of temperature and recycle ratio are independently made of upstream operations thereby lessening the effects on overall plant equilibrium.

Still a further object of the present invention is to produce a secondary bitumen froth having higher quality on a consistent basis thereby relieving downstream operations of the problems associated with variable froth quality and process stream temperature fluctuation.

Still a further object of the present invention is to provide a method and apparatus to improve secondary froth

quality which is readily amenable to automatic control thereby relieving plant operators of the need to undertake special or manual adjustments to the controls or the system. For example, the prior necessity for flushing, steaming or dumping within the system is eliminated with respect to the secondary froth recovery circuit.

A still further object of the present invention is to provide a heat exchanger for a froth cleaner underflow stream which may be conveniently located within or outside of the plant for maintenance and utility input without adversely impacting the remaining operation. Repair and maintenance requirements are therefore minimized.

Another object of the present invention is to provide a tar sand extraction process which is adapted to treat lower grade tar sand ore of the type which tend to produce an increased amount of secondary froth.

It is a further object of the present invention to provide a flotation froth treatment method and apparatus whereby the secondary froth is intimately contacted with heated underflow from the froth cleaner immediately prior to treatment by the froth cleaner to improve the quality of the secondary froth.

It is another object of the invention is to provide a hot water extraction process whereby sensitivity of the extraction process to variations in tar sand feed grade is diminished.

Figure 1 is a schematic diagram illustrating the present invention incorporated within a hot water extraction circuit.

Figure 2 is a schematic diagram illustrating an alternative embodiment of the present invention.

Figure 3 is a schematic diagram illustrating another alternative embodiment according to the present invention.

Turning to Figure 1 of the drawings, tar or oil sand ore to be treated is directed through line 2 into a digestor or extraction drum 4. Hot water, steam and a chemical, for example sodium hydroxide are added to the digestor 4 to produce a slurry. The residence time within the digestor 4 is usually about five minutes and the final slurry has a temperature of about 80 degrees Celcius. The rate of hot water and sodium hydroxide addition is a function of the amount of oil sand feed as well as the grade of the oil sand feed the adjustment of which is well known in the art.

The slurry, prepared and conditioned in the digestor 4 is then withdrawn by gravity flow or otherwise through conduit 6. It is screened through a vibrating screen 8 to remove from the oil sand slurry any debris, rocks or oversized lumps which are directed to outlet 10. The screened slurry enters line 12 where it may be diluted with additional water from line 14. Water addition is dependant

upon the quality of the oil sand ore being treated. For example, in the event the clay content of the oil sand ore is high, a high rate of fresh water may be added to compensate for the high clay content. Modifications to this portion of the process stream concerning water addition, temperature and steam are well known to those of ordinary skill in the art.

The conditioned slurry continues from line 12 into a primary separation vessel 16. As is known in the art, the primary seperation vessel 16 contains a relatively quiescent body of hot water. In the vessel, the treated slurry forms into a bitumen froth layer which rises within the vessel and is withdrawn via line 18 from the top of the vessel. This froth layer is referred to as primary froth comprising bitumen plus entrapped water and solids. The primary froth overflows the primary separation vessel 16 and is received in a launder extending around its rim. The primary froth typically comprises about 67% bitumen, 8% solids and 30% water and has a temperature of about 175 degrees Fahrenheit.

A middlings stream typically comprising about 2.3% bitumen, 21% fine solids and 76.8% water is withdrawn via line 20 from the mid-section of the primary separation vessel for secondary treatment as will be discussed below. Coarse sand particles and other solids settles out into the

conical bottom of separation vessel 16 and are removed as tailings via underflow line 22 to enter tailings oil recovery vessel 24.

The tailings oil recovery vessel 24 comprises a generally cylindrical upper section having a conical lower section and is of the type as described in U.S. Patent 4,545,892 the pertinent tailing oil recovery vessel 24 functions to extract any bitumen which may have escaped the primary separation vessel via tailings in line 22. The tailings oil recovery vessel 24 produces three streams including a secondary froth stream 26 which is directed for further treatment in the froth cleaner 40 of the secondary froth recovery zone A. A middlings stream 28 is removed, and combined with middling stream 20 from the primary separation vessel 16 for additional treatment as will be described below. A tailing stream 30 directs sand from which bitumen has been extracted for subsequent disposal.

Turning now to the secondary recovery circuit generally shown as A in Figure 1, the present invention can be seen in greater detail. The combined middlings streams 20 and 28 from the primary separation circuit are directed to a sub-aeration flotation cell 34 via line 32. This middling stream typically contains about 2.3% bitumen, 21% fine solids and 76.8% water. The flotation unit 34 according to the present invention may include a number of

individual flotation cells in series, each of which is equipped with an agitator capable of vigorously agitating the middling and a distributor through which air is introduced into the individual cells. Underflow from a first cell is advanced to a second and continues in series along the entire flotation unit 34 with underflow from the final cell being discarded as a tailing stream 36.

A froth layer comprising bitumen extracted from the middling stream, some water and solids flows to the surface of the flotation cell 34 and is removed through line 38. The flotation froth typically comprises about 25% bitumen, 12% solids and 46% water. It is recovered in a launder associated with the flotation cell 34 prior to entering secondary froth stream 38. The secondary flotation froth within stream 38 is directed for eventual entry into a froth cleaner 40. The middlings streams which enter the flotation froth thereby contaminating stream 38. Since such contamination causes difficulties with downstream operations, the stream passes to a settling vessel otherwise known as a froth cleaner 40 where water and mineral settle out to be later removed as underflow 42 via underflow pump 44. A froth cleaner is similar to the primary separation vessel in construction but smaller. The interface within the froth cleaner 40 between the secondary froth and the slurry is maintained by adjustment to the

speed of underflow pump 44. High quality bitumen froth overflows the lauders of the froth cleaner 40 and is removed via line 46 for treatment to extract bitumen product. It may be heated prior to being combined with the primary froth in line 18 to form a single high quality froth product stream having a high bitumen content. Treatment usually includes reheating the high bitumen froth stream and deaerating followed by dilution with naphta and centrifugation to recover a clean, dilute bitumen product.

As noted earlier, the froth cleaner underflow stream comprises a middlings-like slurry which is extracted by underflow pump 44 and redirected via line 48 for recycle to the flotation cell 34. However, in this invention, a portion of this underflow stream is diverted via valve 50 from line 48 into a recycle line 52. The diverted underflow stream within recycle line 52 is then heated by an indirect contact heat exchanger 54. A shell and tube type heat exchanger may be used. Because the underflow stream which is being recycled has a very low bitumen content, its heat transfer coefficient is high and a relatively small heat exchanger will suffice.

The recycled stream is heated to a temperature less than about 98 degrees Celcius. However, this temperature can be adjusted to stabilize the temperature of the froth cleaner in an effort to obtain optimum performance. In a

preferred embodiment the froth cleaner temperature is about 75 degrees to about 80 degrees Celcius. The temperature will vary depending upon upstream temperatures driving the secondary froth temperature. The heated underflow stream is combined with the secondary froth stream within line 38 prior to introduction into the froth cleaner 40 as shown in the drawings. In a preferred embodiment, the preheated underflow is recycled with the flotation froth from flotation cell 34 in a ratio of about 1:1.

The combined flotation froth stream 38 and heated underflow stream 52 enter froth cleaner 40 via line 56 as a froth cleaner feed stream. Since the recycled underflow from the froth cleaner 40 has been preheated, its addition to the froth cleaner feed stream will slowly raise froth cleaner temperature until it stabilizes to a temperature above that of the upstream secondary flotation froth stream 38. Froth cleaner temperature depends upon numerous factors such as the proportion of underflow that is recycled, the temperature to which the underflow recycle is heated and temperature losses from piping or to the atmosphere between the points of injection and the froth cleaner.

The present invention is self limiting as to froth cleaner temperatures since even if the recycle stream is near boiling, if the recycle ratio is also high, froth cleaner temperature will not be excessive. As is readily

apparent, an appropriate control with feedback may be installed as is known in the art to automatically regulate the recycle and heating of the underflow prior to injection into the froth cleaner 40. The control will operate the variable speed pump and valve to vary recycle into the heat exchanger. The froth cleaner temperature would be monitored via a feedback loop to direct heated underflow into the cleaner as required.

The recycle ratio and operating temperatures of the recycled underflow can therefore be adjusted to achieve optimum operation and performance of the froth cleaner independent of upstream operations. In addition, since the secondary extraction circuit is no longer temperature dependant upon the primary extraction circuit, the primary extraction circuit temperatures can be lowered nominally to 55 degrees Celcius or to the point beyond which it is known that overall recovery is reduced. As a result, the secondary extraction circuit is no longer as dependent upon temperature of the secondary froth entering the circuit. In addition, because the bitumen froth removed from the froth cleaner is of a consistently high quality, downstream operations to treat the froth and extract the bitumen product are enhanced since there is no longer the problem associated with cycling or variable froth quality and temperature. The prior requirement of periodic flushing,

steaming and dumping of the system due to contamination and overflow of the secondary froth is no longer necessary since the secondary froth is maintained at an optimum temperature and quality prior to introduction into the froth cleaner thereby increasing the efficiency of the froth cleaner. Lastly, pumpability of the treated secondary flotation froth from the cleaner is vastly improved.

Turning now to Figure 2, an alternative embodiment of the present invention as directed to the secondary recovery circuit is shown. As with the embodiment shown in Figure 1, a middlings stream 58 enters a flotation cell unit 60 from which flotation froth stream 62 and flotation tailing stream 64 are removed. A froth cleaner 66 is provided to treat the flotation froth. An underflow line 70 extract the underflow from froth cleaner 66 via pump 72 for eventual recycle via line 74 into the flotation cell 60. A recycle line 76 including recycle pump 78 and valve (not shown) is also provided to remove a separate portion of the froth cleaner underflow for recycle into the secondary froth feedstream 63 of the froth cleaner 66. A heat exchanger 80 is also provided to reheat the overflow prior to recycle into the secondary froth feedstream 63 of froth cleaner 66. As is readily apparent, this embodiment provides a direct recycle circuit extending from the froth

cleaner 66 and to the flotation froth feedstream 63 without the need for a separate control system to operate a control valve and diverts underflow from a single underflow stream and pump. Upgraded froth is removed via line 68.

Turning now to Figure 3, an additional alternative embodiment of the present invention is also shown. A middling stream 82 is produced from the primary extraction circuit, the majority of which is diverted to flotation cell 84. The flotation cell 84 produces a flotation froth stream 86 which is directed to the froth cleaner 88 for eventual treatment. A high quality froth is removed from the froth cleaner 88 via line 90 for subsequent treatment while an underflow is extracted through line 92 for recycle into flotation cell 84 via underflow pump 94. The middling stream 82 further includes a control valve 96 which selectively diverts a portion of the middling stream 82 into line 98 where it is appropriately heated by heat exchanger 100 and combined with froth stream 86 to produce a secondary froth feedstream 87. As with the embodiment shown in Figure 1 and Figure 2, the temperature of the diverted middling stream and the ratio of which it is added to the froth stream 88 can be controlled via automatic control means (not shown).

While this invention has been described as having a preferred design, it is understood that it is capable of

further modifications, uses and/or adaptations of the invention following in general the principle of the invention and including such departures from the present disclosure as come within the known or customary practice in the art to which to invention pertains and as may be applied to the central features hereinbefore set forth, and fall within the scope of the invention and of the limits of the appended claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method to upgrade the quality of secondary froth obtained from a hot water extraction process and improve treatment thereof comprising the steps of:

a) providing a froth cleaner unit;

b) passing a flotation froth stream into the froth cleaner for treatment;

c) removing a low-bitumen content underflow stream from the froth cleaner;

d) reheating at least a portion of the removed underflow stream; and

e) combining the reheated portion of the removed underflow stream with an untreated flotation froth stream prior to passing into the froth cleaner for treatment thereby upgrading the quality the cleaned secondary froth that is removed from the froth cleaner unit.

2. A method as set forth in claim 1 and wherein:

a) reheating the at least a portion of the removed underflow stream to about 95 degrees Celcius prior to combining with the untreated secondary froth stream.

3. A method as set forth in claim 1 and wherein:

a) the reheated portion of the underflow stream is combined with the untreated flotation froth stream at a ratio of about 1:1.

4. A method as set forth in claim 1 and wherein:

a) spraying the combined reheated underflow stream and untreated flotation froth stream into the froth cleaner unit.

5. A method as set forth in claim 1 and wherein:

a) reheating the portion of the removed underflow stream with a shell and tube indirect contact heat exchanger.

6. A method as set forth in claim 5 and further comprising the steps of:

a) removing a second underflow stream from the froth cleaner unit; and

b) treating the second underflow stream to produce additional secondary froth.

7. A method as set forth in claim 6 and wherein:

a) the second underflow stream is treated with a flotation cell.

8. A method as set forth in claim 1 and further including the steps of:

a) treating all of the removed underflow stream to produce additional secondary froth;

b) removing a second underflow stream having low-bitumen content from an upstream source within the hot water extraction process;

c) reheating at least a portion of the removed second underflow stream; and

d) combining the reheated portion of the removed second underflow stream with the untreated secondary froth stream prior to passing into the froth cleaner for treatment.

9. A method as set forth in claim 8 and wherein:

a) the second underflow stream is a middling stream produced by a primary separation vessel.

10. An improved hot water extraction process for removing bitumen from oil sands wherein primary and secondary froth streams are produced by a primary separation vessel and secondary flotation cell respectively and a froth cleaner unit is provided to treat the flotation froth stream, the improvement comprising the following steps:

a) passing the flotation froth stream into the froth cleaner for treatment;

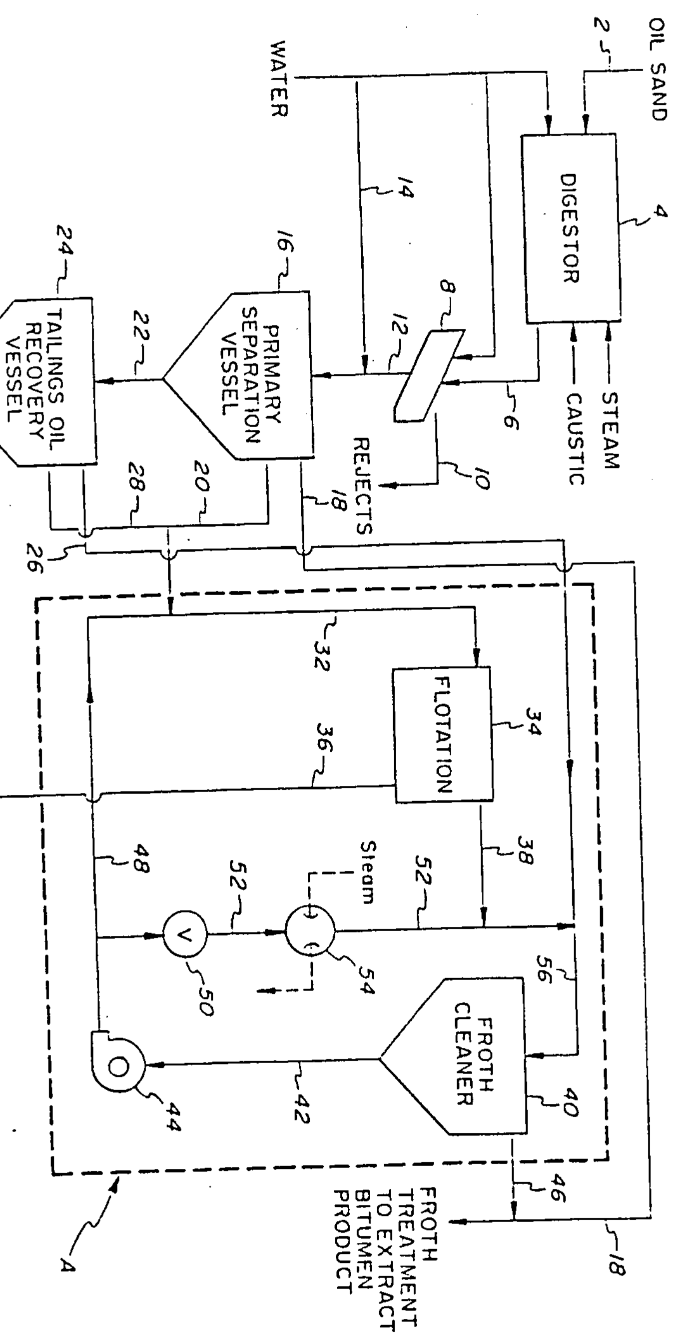
b) removing an underflow stream from the froth cleaner;

c) reheating at least a portion of the removed underflow stream;

d) combining the reheated portion of the removed

underflow stream with untreated flotation froth stream prior to passing into the froth cleaner for treatment thereby improving the quality of the cleaned secondary froth after removal from the froth cleaner unit; and

e) combining the cleaned secondary froth with the primary froth stream for subsequent treatment to extract bitumen therefrom.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8
12
6
10
REJECTS
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16
22
TAILINGS OIL RECOVERY VESSEL
24
20
28
18
26
30
32
FLOTATION
34
36
38
Steam
52
54
48
50
56
FROTH CLEANER
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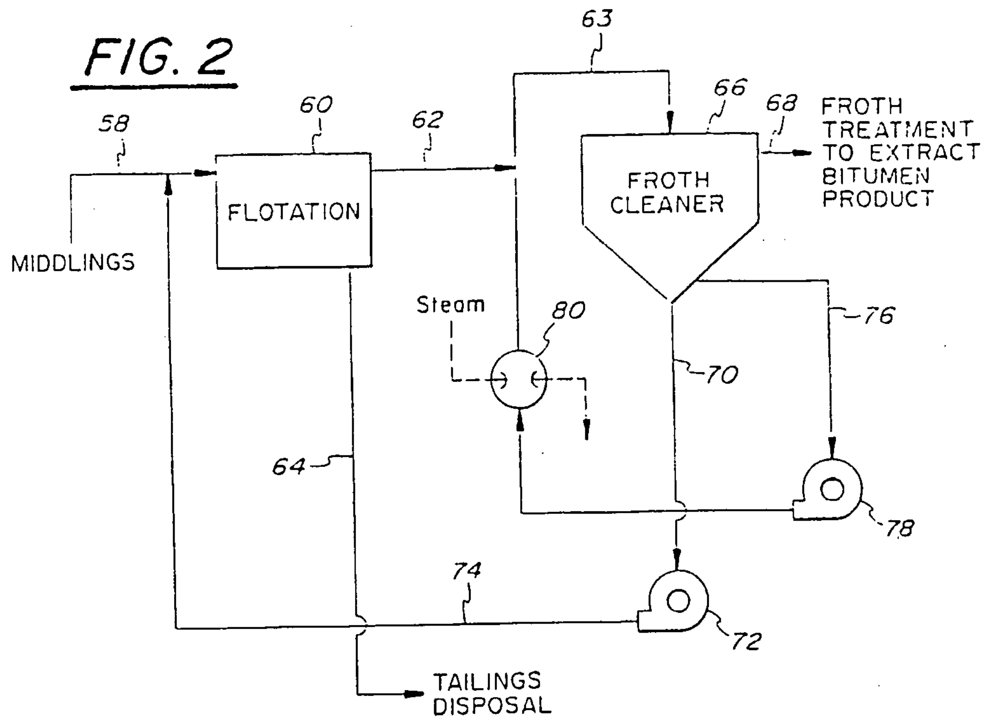
44
46
FROTH TREATMENT TO EXTRACT BITUMEN PRODUCT
18
A
TAILINGS DISPOSAL

FIG. 1

FIG. 2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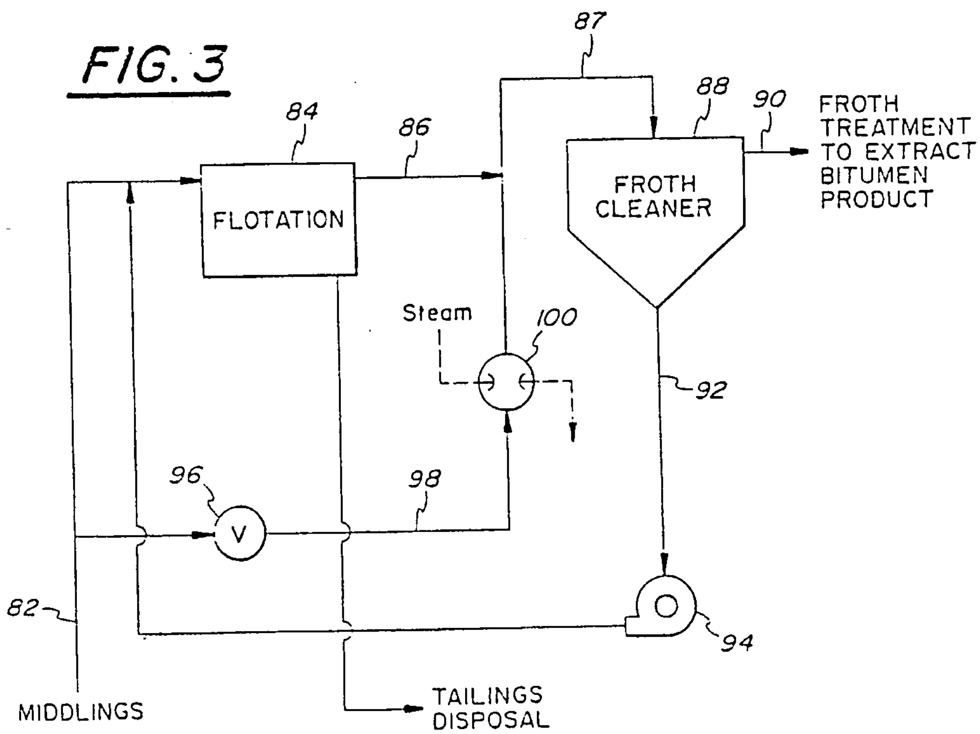
TAILINGS DISPOSAL

FIG. 3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MIDDLINGS
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